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Evaluations of Plastic Mesh Tubes for Protecting Conifer Seedlings from Pocket Gophers in Three Western States

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ABSTRACT: *The efficacy of plastic mesh tubes for protecting conifer seedlings from pocket gopher damage was evaluated on three national forest lands in three states. In each area, cohorts of 640 protected seedlings and 640 unprotected seedlings (3,840 total) were individually monitored for damage, survival, and growth twice each summer for 5 yr after planting. Substantial differences were found between protected and unprotected seedlings for time until occurrence of damage, survival time, proportion damaged and proportion surviving, as well as differences in growth. Over the three forest study sites, the proportion of unprotected seedlings damaged ranged from 60–89%, whereas the proportion of protected seedlings damaged after 5 yr ranged from 18–27%. The proportion of unprotected seedlings that died of gopher damage over 5 yr ranged from 46–64%, versus 1–19% for protected seedlings. Height growth was 25% greater for protected seedlings. Even when only undamaged seedlings were considered, protected seedlings exhibited superior height growth, possibly due to a more favorable microclimate provided by the tubes. These results were reflected in the higher and more uniform stocking rates for protected seedlings. West. J. Appl. For. 14(2):86–90.*

Damage to planted conifers by pocket gophers (*Thomomys* spp.) is a major concern of forest managers in the western United States because damage by gophers probably exceeds that by all other species combined (Crouch 1986). Gophers damage conifers at almost all stages of stand development, but the most severe damage generally occurs during early regeneration, principally from gophers cutting or gnawing off roots and main stems of seedlings. This commonly results in seedling mortality and eventual understocking, or suppressed seedling height growth and regeneration delay. Reducing damage during the first few years after planting minimizes this effect (e.g., Barnes 1973).

Control methods presently available to land managers, which include trapping and machine or hand application of toxic grain baits, generally are aimed at population reduction. These methods, however, have not adequately reduced seedling losses because of limitations in operational programs, re-invasion, and other problems inherent to direct population control (e.g., Barnes 1973, Capp 1976, Sullivan 1986). In addition, there is an increasing public interest in the use of nonlethal means to reduce animal damage (Acord 1992). Indirect population control by reducing abundance of required foods with herbicides (Black and Hooven 1974, Borrecco 1976, Engeman et al. 1995, 1997b) is one promising approach to the pocket gopher reforestation problem but may face regulatory restrictions in some situations.

Mechanical barriers provide an alternative to controlling gopher populations as a means of reducing damage (e.g., Marsh et al. 1990). Wire cages around individual seedlings were shown to deter animal damage (Black et al. 1969), but caging was not practical until the development of plastic mesh tubes as seedling protectors (Campbell and Evans 1975). Seedling protectors were originally developed for reducing aboveground feeding injuries to Douglas-fir (*Pseudotsuga menziesii*) by lagomorphs and big game animals but since have been applied to pocket gophers in many areas. This paper reports on a 5 yr study of

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plastic mesh seedling protectors to reduce pocket gopher damage to two species of conifer seedlings.

Materials and Methods

Seedling Protector

The protector used in our evaluations was a 76 cm long Vexar® cylinder of photodegradable, polypropylene plastic netting (reference to trade names does not imply U.S. Government endorsement of commercial products) with an inside diameter of 5 cm, a mesh opening of 9 mm, and strand diameter of 1.5 mm (DuPont code: 2-in ID 60-PDP-27, translucent green). Decomposition of this device is caused by ultraviolet radiation, and there are no known environmental hazards associated with the plastic or its by-products (Campbell and Evans 1975).

Study Areas and Planting

Areas selected for study were representative of forest types in which gophers most severely affect reforestation. Study areas were located in northern California, central Oregon, and eastern Idaho. Within each area, specific study sites were selected based on past history of reforestation failure due to gophers, uniformity of gopher distribution, and homogeneity of vegetative composition and distribution. In northern California, a study site was established in the Klamath National Forest (KNF) on high-elevation (1800 m) clearcuts, terraced for planting. Shasta red fir (*Abies magnifica* var. *shastensis*) seedlings were planted. In central Oregon, a high-elevation (1700 m) lodgepole pine (*Pinus contorta*) community was chosen for study in the Deschutes National Forest (DNF). Slash had been machine piled and burned prior to planting lodgepole pine. The third site was established in eastern Idaho in the Targhee National Forest (TNF) on large (> 40 ha) clearcuts located in a high (1900 m) caldera occupied by lodgepole pine forests. The gopher species on the KNF study site was the Mazama pocket gopher (*Thomomys mazama*), and the northern pocket gopher (*T. Talpoides*) was present on the DNF and TNF sites.

The DNF site was comprised of four clearcuts 6 to 10 ha in size. Four 0.4 ha plots were delineated in each clearcut for a total of 16 plots. Within each block there were 10 randomly located 40 m^2 subplots containing Vexar-protected seedlings and 10 other subplots containing unprotected seedlings. Every subplot contained four seedlings individually marked by a numbered wooden stake, providing a sample of 640 protected seedlings and 640 unprotected seedlings. The KNF site was comprised of three clearcuts, into the largest of which were placed eight 0.4 ha plots, while the other two clearcuts had four such plots each for a total of 16 plots. As in the DNF, these plots each contained ten 40 m^2 subplots of Vexar-protected seedlings and 10 subplots of unprotected seedlings. The TNF study site was comprised of large contiguous clearcuts in which 16 plots (0.4 ha) were placed. The subplots and seedlings for study in these plots also were designed as in DNF. Thus, 1,920 sample seedlings each of protected and unprotected (3,840 total) were monitored across the three study sites for the course of the study. The sample comprised about 9% of all planted seedlings on the study sites.

Seedlings were randomly selected to receive the Vexar protectors. The procedure for placing seedlings in protectors began by inserting the bare-root seedling in a solid plastic (polyvinyl chloride) pipe of a slightly smaller diameter than the Vexar tube. This pipe acted as a protective carrier of the seedling during its insertion into the tube. After being positioned so that its lower roots were at the bottom of the tube, the seedling was held in place, and the plastic pipe was removed. Moistened soil, taken from the vicinity of the planting site, was packed through the mesh around the roots of the seedling. Packaged seedlings were carried to the field in burlap bags and auger-planted. The DNF study area was auger-planted in 1976 with lodgepole pine seedlings that were nursery grown for 3 yr. The TNF study area was auger-planted in 1977 in machine-scalped spots with lodgepole seedlings that were nursery grown for 2 yr. The KNF study area was auger-planted on bulldozed terraces in 1976 with Shasta red fir seedlings that were nursery grown for 2 yr. No rodenticide baiting for pocket gopher control was conducted on the study areas from the year prior to planting through the end of the study.

Data Collection and Analyses

Data were collected twice each year, in spring/early summer and in late summer, for 5 yr after planting. During these examinations, seedlings were inspected for damage and mortality, identity of injury sources by animal and nonanimal agents, the extent of damage and vitality. The late summer observations also included measurements of height of the surviving seedlings.

Gopher activity was verified on each unit using eighty 81 m^2 circular plots where mound counts and plugged burrows (Anthony and Barnes 1984) were used to provide a present–absent assessment 48 hr after all gopher sign in each plot had been erased. At least two gopher activity plots were placed in each 0.4 ha plot.

The data from each study site were analyzed separately because sites were characterized either by different species of seedlings, planting practices, or plant communities. Times until the occurrence of first gopher damage and survival time difference between protected and unprotected seedlings were analyzed nonparametrically using Kaplan-Meier (1958) survival analyses and Wilcoxon comparisons of survival curves (Kalbfleish and Prentice 1980). Seedling heights were analyzed using analyses of variance. The percentage of four seedling subplots where at least two seedlings survived gopher damage was used as a measure of uniformity of stocking rate (J. Booser, personal communication) at each study site and was compared between protected and unprotected seedling subplots by applying Fisher's "exact" test.

Results

Time Without Gopher Damage

The results from the survival analyses were similar among the three study sites. The rates at which seedlings were attacked by gophers (Figure 1) were substantially greater for

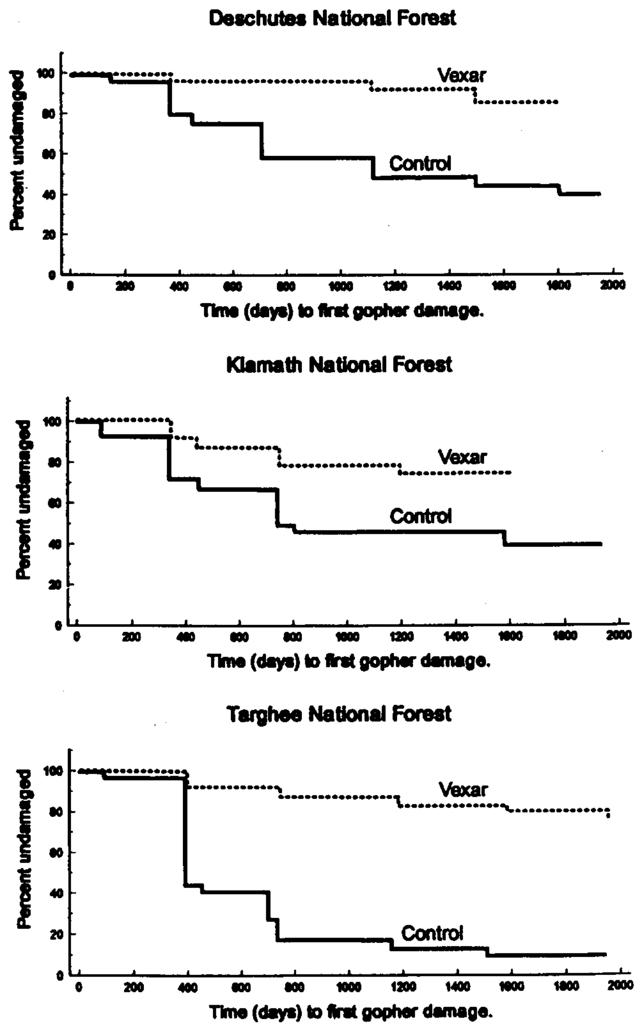

Figure 1. Kaplan-Meier analyses of measurements on time until first gopher damage for Vexar®-protected and Vexar®-unprotected seedlings at study sites in the Deschutes, Klamath, and Targhee National Forests.

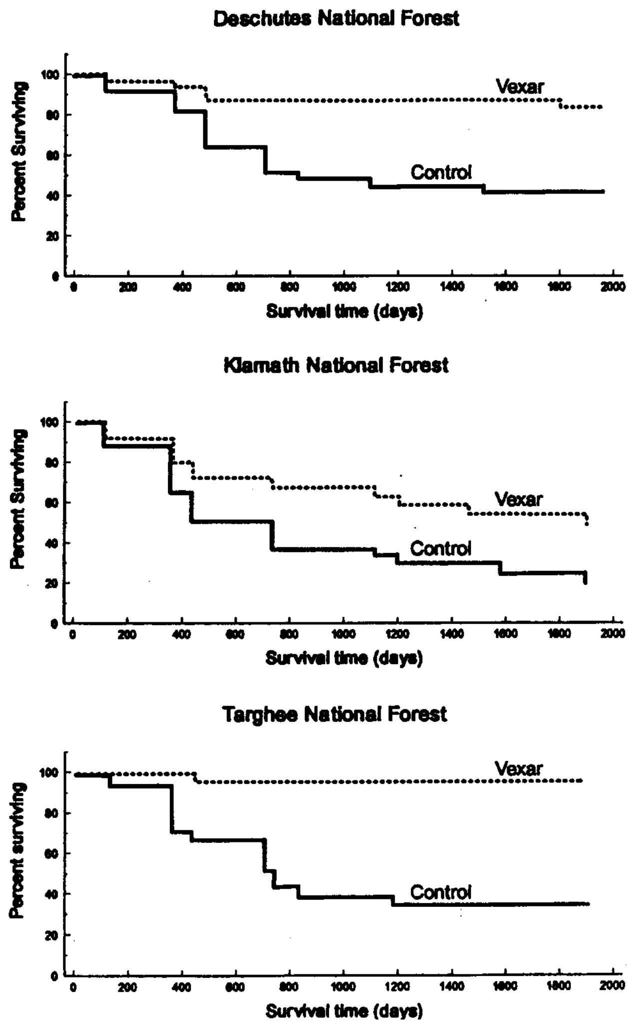

Figure 2. Kaplan-Meier analyses of measurements on survival times for Vexar®-protected and Vexar®-unprotected seedlings at study sites in the Deschutes, Klamath, and Targhee National Forests.

unprotected seedlings than for protected seedlings (Wilcoxon comparison of Kaplan-Meier survival curves $\chi^2 > 117$, df = 1, $P < 0.0001$ for each of the study sites). The magnitude of the differences in the rates of gopher damage over time is reflected in final percentages of seedlings not damaged by gophers. For DNF, 40% of unprotected seedlings never received gopher damage versus 82% of the protected seedlings. Similarly, 43% of the unprotected seedlings at KNF were damage-free after 5 yr compared to 75% of the protected seedlings. The differences were even greater at TNF where only 11% of unprotected seedlings remained free of damage while 73% of the protected seedlings were undamaged.

Seedling Survival

Perhaps more important than the damage rates, the survival results further emphasized the differences between the use of Vexar and no seedling protection. As would be expected from the above results, substantial differences in survival (Figure 2) existed between protected and unprotected seedlings (Wilcoxon comparison of Kaplan-Meier survival curves $\chi^2 > 73$, df = 1, $P < 0.0001$ for each of the study sites). The final survivals of unprotected seedlings were 37%, 24%, and 32%, respectively, for DNF, KNF, and TNF. Survival of protected seedlings, however, for the same sites were 81%, 48%, and 95%, respectively, two to three times greater than for the unprotected seedlings.

Further examination revealed that the percentage of protected seedlings that died due to gopher damage was considerably less than the percentage for unprotected seedlings. On the DNF study site, only 2% of protected seedlings died of gopher damage, in contrast to 46% of unprotected seedlings. In the KNF, gophers killed 19% protected seedlings versus 54% of unprotected seedlings. The greatest discrepancy between protected and unprotected seedlings occurred on the TNF where 64% of unprotected seedlings, and 1% of protected seedlings were killed by gophers.

Seedling Heights

Random samples of initial seedling heights at planting were made for 100 protected and 100 unprotected seedlings at DNF and TNF. No differences in initial heights were indicated between protected and unprotected seedlings at DNF (23.5 and 23.2 cm, respectively). Protected seedlings at TNF on average, however, were taller than unprotected seedlings at planting (19.6 cm vs. 17.3 cm), possibly indicating a slight visual bias against using smaller seedlings in the tubes. Therefore, we considered comparing heights only for DNF at the conclusion of the study, where we felt confident that baseline differences did not exist between protected and unprotected seedlings. Analyses of the final height data provided an indication of a beneficial effect from the seedling protectors. Overall, the mean height of surviving seedlings at DNF 5 yr after planting was 86 cm for protected, versus 69 cm for unprotected ($F = 24.17$, df = 1,3, $P < 0.0001$). We also compared the heights of only those seedlings that received no damage. Although the seedlings in plastic mesh tubes had greater mean heights than unprotected and undamaged seedlings, 88.1 cm versus 76.8 cm, this difference was not detectable statistically ($P > 0.15$).

Stocking Rates

The comparisons among stocking rates for protected and unprotected seedlings followed patterns that would be expected from the survival data. That is, for each site the proportions of subplots with two or more surviving seedlings were more than twice as great when Vexar tubes were used as when no protection was applied (Fisher's test $P < 0.0001$ for each site). All subplots with protected seedlings in the TNF had more than two surviving seedlings versus 37% for unprotected seedlings. The results were nearly as good for the DNF where 97% of the subplots with protected seedlings had more than two surviving after 5 yr, compared to 44% for unprotected seedlings. Final stocking rates were not as good at KNF where factors other than gophers substantially affected survival, with 59% of protected seedling subplots having more than two surviving seedlings, as opposed to only 27% for the unprotected seedling subplots.

Discussion

Over the 5 yr in which the seedlings were monitored, the Vexar plastic mesh seedling protectors greatly reduced the rate of gopher damage and gopher-caused mortality in each of the three geographically distinct areas of the western United States. Beyond that, the overall survival rates of the seedlings when all hazards were considered together were two to three times as great for protected seedlings as unprotected seedlings.

Protection from gopher damage may not be the only benefit offered by the seedling protectors. Other factors may influence the heights of protected seedlings. Comparisons of undamaged seedlings after five growing seasons indicated that mean heights of protected seedlings may be greater than for unprotected seedlings. Borrecco (1976) made similar observations studying Douglas-fir and hypothesized that stem movement from wind, which inhibits height growth (Neel and Harris 1971), is reduced inside the protector. Another possibility is that the protectors provide a beneficial shading effect. Regardless of the cause, the possibility that plastic mesh protectors may promote growth in addition to survival deserves further attention.

One possible concern with the use of plastic seedling protectors has been that without exposure to sunlight, buried portions might degrade too slowly and cause root constriction. Owsten and Stein (1978) and Ellis (1972), using seedling containers with thicker plastic and more dense mesn patterns than that of the protectors studied here, respectively noted root deformities in Douglas-fir and black walnut (*Juglans nigra*). Engeman et al. (1997a), however, reported Vexar-protected lodgepole pine roots to be as healthy or more so than unprotected roots.

Besides the reduction in pocket gopher damage and apparent height gains demonstrated in our study, "Vexar" protectors have been shown effective against other animals (Campbell and Evans 1975, McPhee 1975, Borrecco 1976), some of which inhabit the same areas with high gopher damage. On some areas, then, use of protectors generally would require just one commitment of labor (at planting time), whereas other available control measures usually involve several commitments and exact timing. Baiting, for example, must be done periodically (e.g., Sullivan 1986) for several years. Also, the great gains in survival and stocking uniformity when using the protectors imply that lower planting rates could achieve desired tree density. Hence, when using plastic mesh barriers, both control efficacy and efficiency should be scrutinized.

Earlier studies of "Vexar" protectors indicated that protrusion of terminal stems of Douglas-fir was of minor consequence (Campbell and Evans 1975, Borrecco 1976); however, terminal protrusion might vary among conifer species. In our study, terminal deformity was negligible in lodgepole pine, but common in red fir. Because red fir seedlings tend to develop multiple terminals, the ultimate effect on seedling growth may not be pronounced.

Anyone considering the use of "Vexar" protectors for gopher damage control should weigh a number of factors, including cold breakage, terminal deformity, snow compression, and cost; the relative importance of these factors should be evaluated according to the specific conditions of each damage situation. For example, cold breakage of seedling protectors occurred infrequently in our study. Nevertheless, an awareness of critical temperatures and careful handling will be necessary to avoid the problem during operational planting. Furthermore, tube breakage could be a serious problem on plantations that incur heavy use by big game or livestock during subfreezing temperatures. Snow compression is another problem that could be expected to vary in importance according to local conditions.

Economics probably will be one of the foremost concerns of many forest managers when contemplating use of plastic protectors. Using our packaging technique, the cost of planting protected seedlings could be two to three times that of planting bare-root seedlings. These costs certainly could be lowered with improvements in the preparation, transportation, and planting of enclosed seedlings, or perhaps by using containerized seedlings that could be inserted into protectors at the planting site.

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